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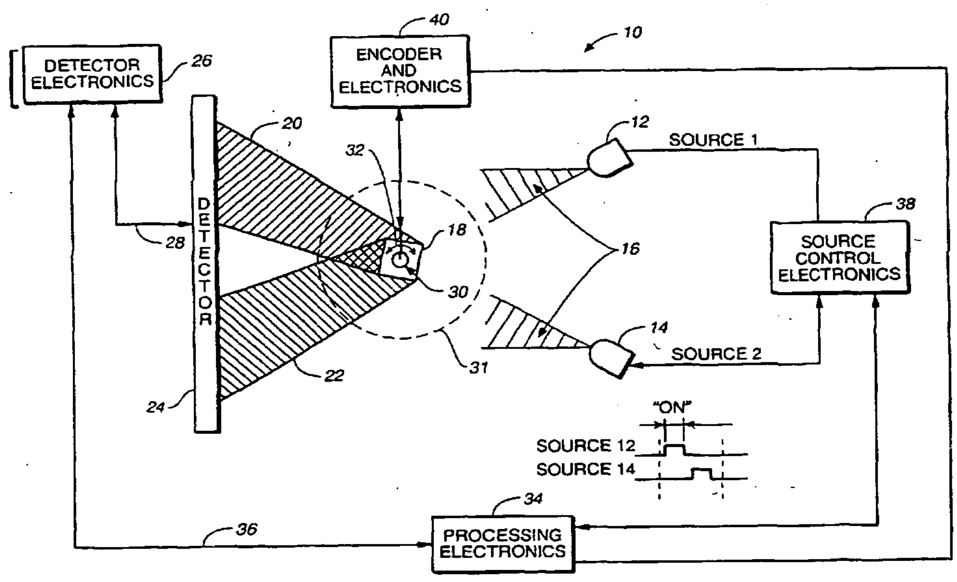
(54) Title: IMPROVED LASER ALIGN SENSOR FOR POSITIONING COMPONENTS




(57) Abstract: A sensor (184) for sensing placement information of a component (18) to be placed by a pick and place machine (150) is disclosed. The sensor (184) includes a plurality of light sources (12, 14) each of which is disposed to direct illumination at different angles of incidence upon the component (18). Each source (12, 14) is further adapted to generate light based upon an energization signal. Source control electronics (38) are provided and coupled to the plurality of light sources (12, 14) to successively provide energization signals to each source (12, 14). A detector (24) is disposed within the sensor (184) relative to the plurality of sources (12, 14) to receive at least one shadow (20, 22) of the component (18), and provide data at a detector output indicative of the shadow (20, 22) imaged while the component (18) is rotated.

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# IMPROVED LASER ALIGN SENSOR FOR POSITIONING COMPONENTS

## BACKGROUND OF THE INVENTION

The present invention relates to control systems which align electrical components for precise placement via pick-and-place systems onto surfaces such as printed circuit boards, hybrid substrates containing circuitry traces, and other carriers of circuit tracings. More specifically, the present invention relates to a non-contact laser-based sensor system which precisely determines angular orientation and location (x, y) of components to allow a pick and place machine to correct angular orientation of the component with respect to the pick and place machine's coordinate system for proper placement.

The electronic device assembly industry uses pick and place machines to automatically "pick" components from standardized feeder mechanisms, such as tape reels, and "place" such components upon appropriate carriers such as printed circuit boards. A given printed circuit board may include a large number of such components and thus the automation of component placement upon the printed circuit board is essential for cost effective manufacture. One important aspect of a given pick and place machine is the manner in which component orientation and location are detected prior to placement. Some pick and place machines transport the component to an

inspection station where it is imaged by an inspection camera, or the like. Once imaged, the controller, or other appropriate device, calculates orientation and location information from the component image. One drawback associated with such systems is the added time required to transport the component to the imaging station; to image the component; and to transport the component from the imaging station to the placement location. Another type of pick and place machine uses an "on-head" sensor to essentially image the component while being transported from the component feeder to the placement location. Thus, in contrast to the above example, on-head component inspection systems typically allow higher component throughput and thus lower cost manufacture.

Pick and place machines that incorporate on-head sensors are known. One such device is taught in U.S. Patent No. 5,278,634 issued to Skunes et al., and assigned to the assignee of the present invention. U.S. Patent No. 5,278,634 discloses an on-head component detector that uses a laser light source to direct laser illumination at and past a component of interest, which laser illumination then falls upon a linear detector. With the laser energized, the component is rotated by the vacuum quill while the image cast upon the linear detector is monitored. This allows angular orientation of the

component, as well as component position to be determined, and corrected for proper placement.

Although the system taught by Skunes et al. has provided a significant advance to the art of electronic component placement in pick and place machines, there exists room for improvement. Such improvement will become apparent upon reading the remainder of this patent document.

## SUMMARY OF THE INVENTION

A sensor for sensing placement information of a component to be placed by a pick and place machine is disclosed. The sensor includes a plurality of light sources each of which is disposed to direct illumination at different angles of incidence upon the component. Each source is further adapted to generate light based upon an energization signal. Source control electronics are provided and coupled to the plurality of light sources to successively and/or selectively provide energization signals to each source. A detector is disposed within the sensor relative to the plurality of sources to receive at least one shadow of the component, and provide data at a detector output indicative of the shadow imaged while the component is rotated.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a top plan view of a pick and place machine for which embodiments of the present invention are particularly useful.

Fig. 2 is a diagrammatic view of a system for detecting component orientation and location in accordance with an embodiment of the present invention.

Fig. 3 is a diagrammatic view of a system for detecting component orientation and location in accordance with another embodiment of the present invention.

Fig. 4 is a diagrammatic view of a system for detecting component orientation and location in accordance with another embodiment of the present invention.

Fig. 5 is a diagrammatic view of a system for detecting component orientation and location in accordance with another embodiment of the present invention.

Fig. 6 is a diagrammatic view of a system for detecting component orientation and location in accordance with another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a top plan view of pick and place machine 150 for which embodiments of the present invention are particularly useful. Although the description of Fig. 1 will be provided with respect to pick and place machine 150, other forms of pick and place machines such as split gantry designs, can be used. As illustrated in Fig. 1, machine 150 includes transport mechanism 152 that is adapted to

transport a workpiece such as a printed circuit board. Transport mechanism 152 includes mounting section 154 and conveyor 156. Transport mechanism 152 is disposed on base 158 such that the workpiece is carried to mounting section 154 by conveyor 156. Feeder mechanisms 160 are generally disposed on either side of transport mechanism 152 and supply electronic components thereto. Feeders 160 can be any suitable devices adapted to provide electronic components, such as taped feeders.

Pick and place machine 150 includes head 162 disposed above plate 158. Head 162 is moveable between either of feeder mechanisms 160 and mounting section 154. As can be seen, head supports 164 are moveable on rails 166 thereby allowing head 162 to move in the y direction over base 158. Movement of head 162 in the y direction occurs when motor 170, in response to a motor actuation signal, rotates ball screws 172 which engages one of head supports 164 to thereby displace the support 164 in the y direction. Head 162 is also supported upon rail 168 to allow head movement in the x direction relative to base 158. Movement of head 162 in the x direction occurs when motor 174, in response to a motor actuation signal, rotates ball screw 176, which engages head 162 and displaces head 162 in the x direction.

As can also be seen, head 162 includes body 178, nozzle mount 180, nozzles 182, and sensor 184. Nozzle mount 180 is disposed within body 178 and

mounts each of nozzles 182 within body 178. As used herein, "nozzle" is intended to mean any apparatus capable of releasably holding a component. Each of nozzles 182 is movable in the z direction (up/down) and rotatable about the z axis by any suitable actuation members, such as servo motors. Sensor 184 is adapted to acquire image information related to components held by nozzles 182. Sensor 184 includes suitable illumination devices and detection devices such that sensor 184 can provide image information that varies based upon component orientation and off-set. This information is provided to processing electronics 34 to calculate respective component orientations and off-sets.

Fig. 2 is a diagrammatic view of component orientation and placement detection system 10 in accordance with an embodiment of the present invention. System 10 includes sources 12, 14 which are arranged to direct illumination 16 upon component 18 from at least two different angles. Illumination 16 from sources 12, 14 is blocked, to some extent, by component 18 to thereby generate shadows 20, 22, respectively. Shadows 20, 22 fall upon detector 24 which is preferably a linear charge coupled device (CCD) sensor. Detector 24 includes a number of photoelectric elements, or pixels, which acquire charge in relation to light incident thereon during an integration period. Detector 24 essentially captures a linear image of shadows 20, 22 in a brief

instant of time and provides data related to the captured image to detector electronics 26 via link 28.

As component 18 is held, or otherwise affixed to nozzle 30, component 18 is rotated as indicated by arrow 32 while one or both of sources 12, 14 are energized. As can be appreciated, during rotation of part 18, shadows 20, 22 will change size and position based upon the cross sectional area of component 18 obstructing a given beam 16 of illumination. The signal from detector 24 is read, and/or stored during rotation of component 18 such that data from detector 24 is used to compute rotational orientation of component 18 as well as location (x,y) of component 18 with respect to nozzle 30. Detector electronics 26 provides this data to processing electronics 34 via link 36. As illustrated in Fig. 2, processing electronics 34 is also preferably coupled to source control electronics 38 such that processing electronics 34 controls energization of sources 12, 14 during rotation of component 18. Processing electronics can reside within a suitable personal computer and includes appropriate software for computing angular orientation and offset. Processing electronics 34 is also coupled to encoder 40 such that processing electronics 34 is provided with a signal from encoder 40 that is indicative of angular orientation of nozzle 30. Thus, by essentially knowing which

sources are energized, knowing the angular orientation of nozzle 30 as indicated by encoder 40, and by detecting images of the shadows cast by component 30 while rotated, processing electronics 34 computes component orientation and location, given suitable knowledge of the internal geometry of the sensor.

Embodiments of the present invention are designed to be able to extract component information (part size, center offset, and angular orientation, etc.) using both single edge and double edge measurements of the component under inspection. Typically, double edge measurements are used when the dimensions of the part allow the shadows of both edges to fall upon the detector at the same time without overlapping, as illustrated in Fig. 2. Thus, multiple edges of the component can be shadowed onto the detector by different sources within the same time interval. The difference between single edge measurement and double edge measurement is that during the single edge measurement process, only one edge of the part is imaged by any source onto the detector due to the part being of a size such that the other edge of the part is obscured.

In some embodiments, two or more sources are sequenced to reduce elapsed time before image information is collected. This is particularly advantageous when these sources are spaced separately with respect to the plane that is defined by the

sources, and the CCD or imaging array. Since the sources are generally at differing angular positions from each other relative to a line drawn from nozzle 30 normal to the surface of detector 24, each of sources 12, 14 will have its principal ray directed at a different angle with respect to this normal line as incident onto component 18. As used herein, the principal ray is that ray emanating from the center of the illumination generated by the radiation source, nominally referenced from the mechanical axis of the detector body, such that the core of emanated radiation, (which is typically symmetrical) is bisected by the principal ray. This allows the information included in the shadow, such as edge information, to represent a different spatial position of the component, i.e. the edge of one side may be lined up with respect to the source 12 and, in less than 90 degrees of part rotation another side may be lined up with respect to source 14, as illustrated in Fig. 2.

The light sources 12, 14 can be sequenced in any suitable manner. For example, sequencing sources 12, 14 at the full frame readout rate of detector 24, reduces the amount of time that elapses between these sources being sequenced such that the amount of angular rotation of the component during that interval is relatively small. By sequencing the sources so, information derived from both sources individually can be well-defined; and the distance

traveled by the part between any particular source's measurement can be reduced, thus reducing the granularity and enhancing the resolution of the sequence of images from that particular source. Each source allows collection of image information from a different rotational position of the component. Based on the different source locations with respect to the component, information from more than one angular position of the component is measured within a relatively small time interval. The component information can be collected in less time than would be required if a single source, were present and full rotation of the component were required in order to obtain the angular information.

Another important feature of embodiments of the present invention is the ability to create a measurement envelope, or sensing field of varying dimension by accommodating a plurality of sources positioned such that they image components of varying size, i.e., for example if a component is 25 millimeters from side-to-side then a source that is placed 12.5 millimeters from the nominal center of the component and disposed normal to the detector with its principal ray would capture the edge of the component that was rotating. The sources have a specified solid cone angle of light emitted from them so the distance from the nominal center and lateral or roughly parallel to the detector surface as discussed above can be adjusted to account for this

divergence of the source light in order to cast a shadow of the edge of the part. However, a source that is placed with its principal ray pointing at, for example, an 8 millimeter position from nozzle 30 and along the diameter of the component 18 parallel to detector 24 would be blocked, depending on the relative orientation of the solid angle of light as well as the position of the source. Based upon the solid angle of each source 12, 14, each source will illuminate various sections of the component. Depending upon the size of component, the component may or may not have its edge within an illuminated area.

As components are exchanged from small to larger parts, sources having principal rays that are pointed increasingly further along a line parallel to , or lateral from, detector 24, but measured from a line normal to detector 24, through nozzle 30 or the center of rotation of the component will image increasingly large parts' edges by selectively sequencing sources 12, 14. Preferably, sources 12, 14 are disposed to cast shadows from opposite sides of component 18 in the same small time interval. Selection of an appropriate source allows the source to be turned on such that an edge of component 18 can be imaged onto the detector 24. This allows components of varying sizes to be imaged on detector 24 without requiring the use of multiple sensors that

are of a fixed measurement envelope, or sensing field.

Although the description above has focused on embodiments where a single nozzle is disposed within the sensing field, other embodiments can provide any suitable number of nozzles in the sensing field. Fig. 3 is a diagrammatic view of system 20 for detecting component orientations in accordance with another embodiment of the present invention. System 20 includes many of the same or similar elements as system 10 shown in Fig. 2 and like elements are numbered similarly. Fig. 3 illustrates that more than one nozzle 30 can be disposed in the sensing field, such that multiple component orientations and the locations can be imaged substantially simultaneously in order to reduce processing time.

The sensing field is the area between the radiation (light) sources, and the detector, where components placed upon the nozzles will have light directed upon them. In this embodiment, shadows from the components' edges are cast upon detector 24 or detectors. Depending upon the locations of nozzles 30 and sources 12, 14, a particular component 18 could be imaged by illumination from a combination of sources, or by sequencing the various sources 12, 14 such that shadows of the component 18 on any particular nozzle 30 can be distinguished from shadows of components on other nozzles. This has an

advantage of allowing more than one component 28 to be measured in the sensing area at essentially the same time. Further, depending upon the spacing of nozzles 30, the nozzles can hold components of varying sizes, yet still allow measurement of the component to be accomplished while such component are rotated on the nozzles.

Fig. 4 is a diagrammatic view of component measurement system 50 in accordance with another embodiment of the present invention. Fig. 4 illustrates a sensing field where detector 24 comprises two spaced apart detector portions 24A, 24B, each one of which receives light incident from a specific source 12, 14. This allows for the use of smaller detector portions 24A, 24B if necessary, and allows the detector portions 24A, 24B to be packaged separately. In this manner, a very long detector 24 is not required in order to establish the same large component sensing envelope.

Fig. 5 is a diagrammatic illustration of component measurement system 60 in accordance with another embodiment of the present invention. System 60 bears many similarities to system 50, shown in Fig. 4, and like components are numbered similarly. The main distinction between systems 60 and 50 is the relative orientations of detector portions 24A and 24B. Specifically, referring to Fig. 4, faces of detector portions 24A and 24B lie in approximately the same plane, and when viewed in two dimensions,

appear co-linear. However, system 60, shown in Fig. 5, illustrates detector portions 24A and 24B disposed such that detector portions 24A and 24B do not lie in the same plane. Thus, detector portions 24A and 24B of systems 60 do not appear co-linear. Instead, detector portions 24A and 24B are preferably disposed normal to a centerline of illumination from the respective source for each detector portion. For example, detector portion 24A appears to be oriented relative to source 14 such that ends 62 and 64 are equidistant from source 14. Detector portion 24A is also disposed in the plane of shadow 20.

Fig. 6 is a diagrammatic view of component measurement and detection system 70 in accordance with another embodiment of the present invention. System 70 is similar to the embodiment shown in Fig. 2 and like elements are numbered similarly. The main distinction between systems 70 and 10, in Figs. 6 and 2 respectively, is the provision of specular reflective surfaces 72, 74. As can be seen, sources 12, 14 direct their illumination away from detector 24 initially, which illumination falls upon specular reflectors 72, 74, respectively, and is directed toward nozzle 30 and detector 34. This embodiment allows for flexibility in placement of sources 12, 14. Detector 24, as shown in Fig. 6, could also incorporate either of the detector layouts shown in Figs. 4 or 5. However, in embodiments using split detector portions, and specular reflectors, it is

contemplated that one source could utilize a specular reflector while another source could be positioned so that its principal ray is directly incident upon the component, and thus not require a specular reflector.

Operation of embodiments of the present invention generally involve the following steps. The first step is calibrating the source, nozzle and detector positions with respect to each other. There are a number of techniques that can be employed for this operation. For example, calculation of the positions of the various sensor components can be performed by placing the sensor with test components fixed in position in a coordinate measuring machine and then using the coordinate measuring machine to identify the relative position of all of the test components such that the position of the ray that is incident from the light source or sources onto the detector is known with respect to the nozzle position and detector position.

As a second step, the shadow or shadows from each component cast upon the detector by light incident from the source or sources has a characteristic intensity profile that is processed to extract an edge. The edge position can be interpolated to subpixel position. Such interpolation can be effected using any number of techniques including centroid calculation or curve fitting. This, then, relates a particular edge position to an encoder position and a known source ray position.

Then, the defined edge of the shadow provides an (r, theta) pair where theta is the position of the encoder that is on the nozzle shaft or attached to the nozzle shaft indicating its relative angular position, and r is the distance from the source to the edge position on the detector that defines the position of the component at that specific point in angular space and time. The (r, theta) pairs are collected during the rotation of the component on the nozzle. These (r, theta) pairs are used to derive, using known geometric techniques, component information including: component width, component length, nozzle off-set of rotation center x, nozzle off-set of rotation center y, and the angular position of a defined frame of reference of the component with respect to the nozzle angular position. With this information, the component location can be translated into the specific pick and place machine's frame of mechanical reference via software and the component can be properly positioned to be placed upon its target location on the printed circuit board.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention. For example, multiple portions of detector 24 could be placed within the same plane or without the same

plane. Further, such detector portions need not be physically adjacent but may be segments of detectors such that the multiple nozzles' position with respect to the light sources and detectors allow components to be imaged on such detector portions based upon selection of sources that are turned on with respect to components and detector portions.

WHAT IS CLAIMED IS:

1. A sensor for sensing placement information of a component to be placed by a pick and place machine having a nozzle, the sensor comprising:

a plurality of light sources disposed to direct light at different angles of incidence upon the component, each source being adapted to generate light based upon an energization signal;

source control electronics coupled to the plurality of light sources to selectively provide the energization signal to each source; and

a detector disposed relative to the plurality of sources to receive at least one shadow portion of the component, the detector having a detector output providing data indicative of the at least one shadow portion imaged while the component rotates.

2. The sensor of claim 1, wherein all of the light sources are disposed to provide illumination in substantially the same plane.

3. The sensor of claim 2, wherein the detector is disposed in the same plane at the light sources.

4. The sensor of claim 1, and further comprising an encoder operably coupled to the nozzle

to provide an encoder signal indicative of angular orientation of the nozzle.

5. The sensor of claim 1, wherein the detector comprises a plurality of detector portions.

6. The sensor of claim 5, wherein the plurality of detector portions are disposed contiguous to one another.

7. The sensor of claim 5, wherein the detector portions are coplanar with one another.

8. The sensor of claim 5, wherein the detector portions are not coplanar with one another.

9. The sensor of claim 5, wherein each detector portion is disposed to image a different part of the component, and each detector portion provides a group of data based upon an image of the at least one shadow portion, and wherein the groups of data include a characteristic cusp, wherein the characteristic cusp from a first group of data occurs at a different component orientation than a characteristic cusp from a second set of data.

10. The sensor of claim 5, wherein each of the detector portions is disposed to have a principal axis oriented at an angle relative to another detector portion.

11. The sensor of claim 10, wherein the angle is about 90°.

12. The sensor of claim 1, wherein the plurality of light sources comprises at least three light sources.

13. The sensor of claim 1, and further comprising a specular reflector disposed between at least one source and the detector.

14. The sensor of claim 1, and further comprising a specular reflector disposed between the component and the detector.

15. The sensor of claim 1, wherein the source control electronics is further adapted to provide the energization signal to successive sources.

16. A pick and place machine, comprising:

a transport mechanism adapted to receive and move a workpiece relative to the pick and place machine;

a feeder mechanism including at least one feeder adapted to provide a plurality of components;

a placement head adapted to releasably convey components from the feeder mechanism to the workpiece;

a sensor for sensing placement information of a component to be placed by the pick and place machine, the sensor including:

a plurality of light sources disposed to direct light at different angles of incidence upon the component, each source being adapted to generate light based upon an energization signal;

source control electronics coupled to the plurality of light sources to successively provide the energization signal to each source; and

a detector disposed relative to the plurality of sources to receive at least one shadow portion of the component, the detector having a detector output providing data indicative of the at least one shadow portion imaged while the component rotates; and

an encoder coupled to the placement head to provide data indicative of component orientation; and

processing electronics coupled to the encoder, and the sensor, the processing electronics adapted to receive data from the detector output and the encoder, and provide command signals to the source control electronics, the processing electronics computing component placement information based upon data provided during rotation of the component.

17. A pick and place machine comprising:

means for placing components on a workpiece; and

means for sensing component orientation and location prior to placement on the workpiece.

FIG._1A

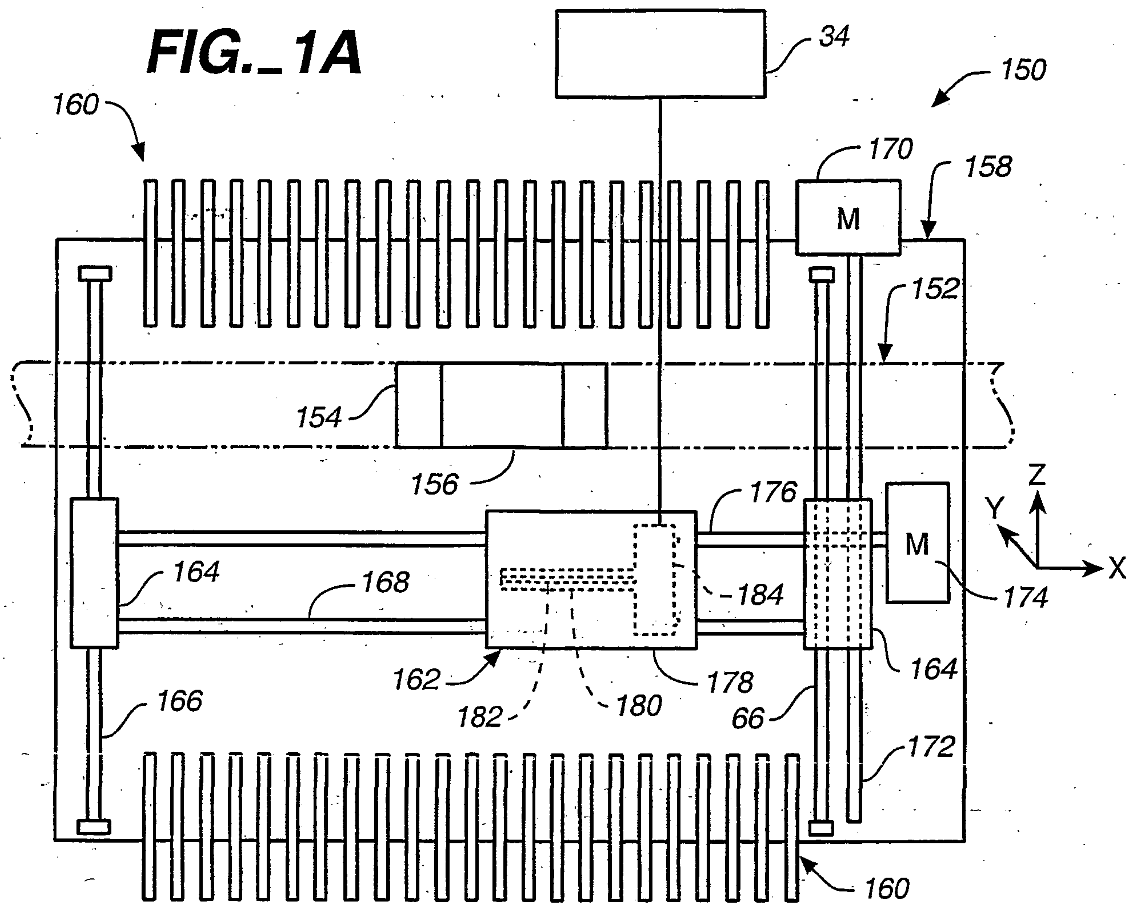
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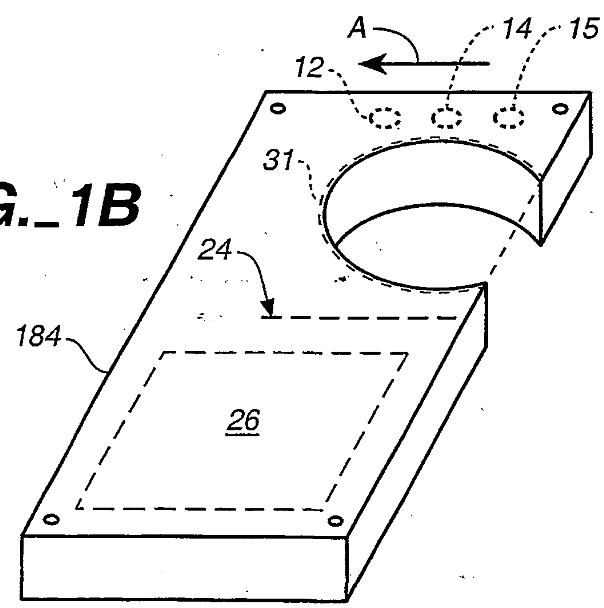
FIG._1B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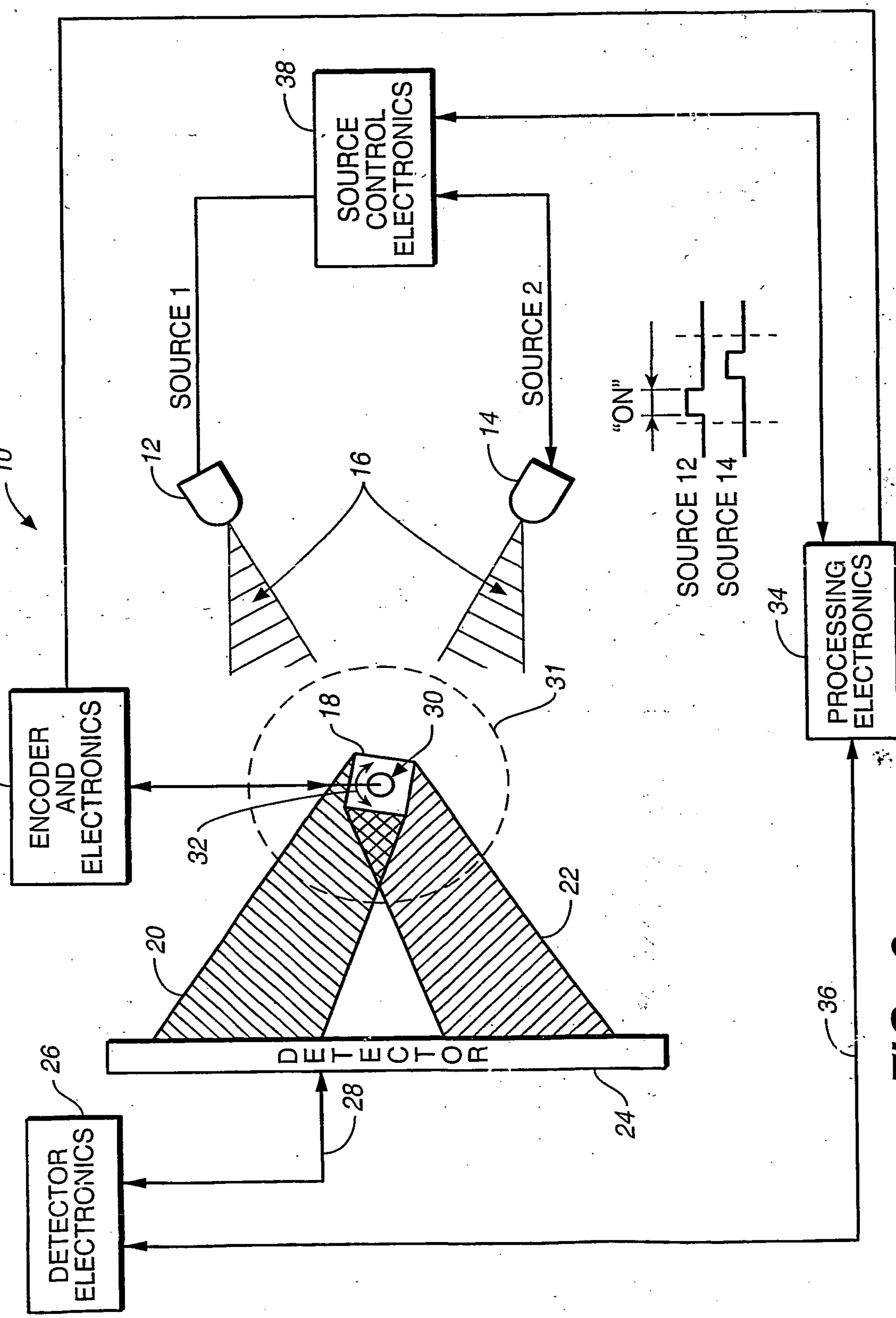
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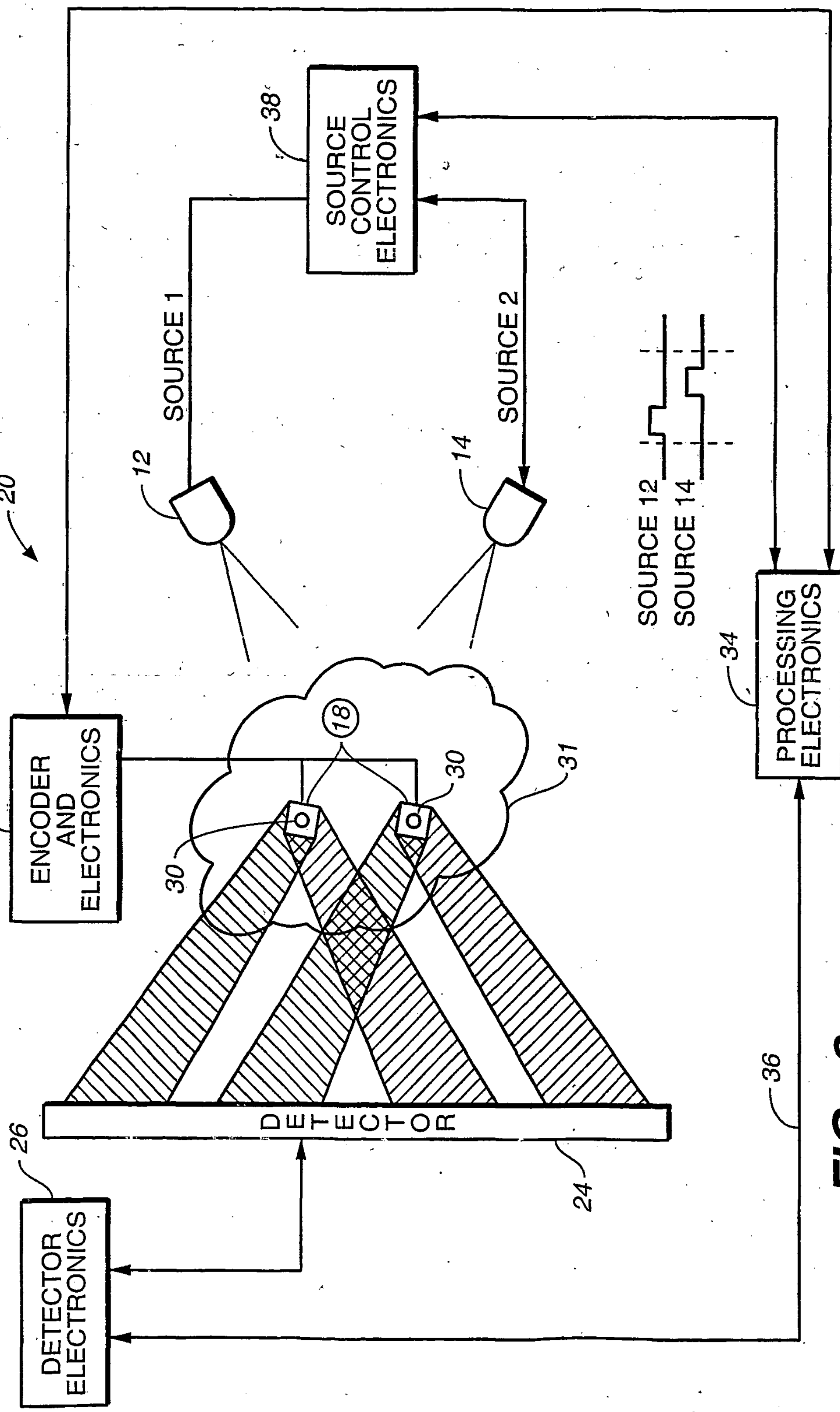
DETECTOR ELECTRONICS

FIG._2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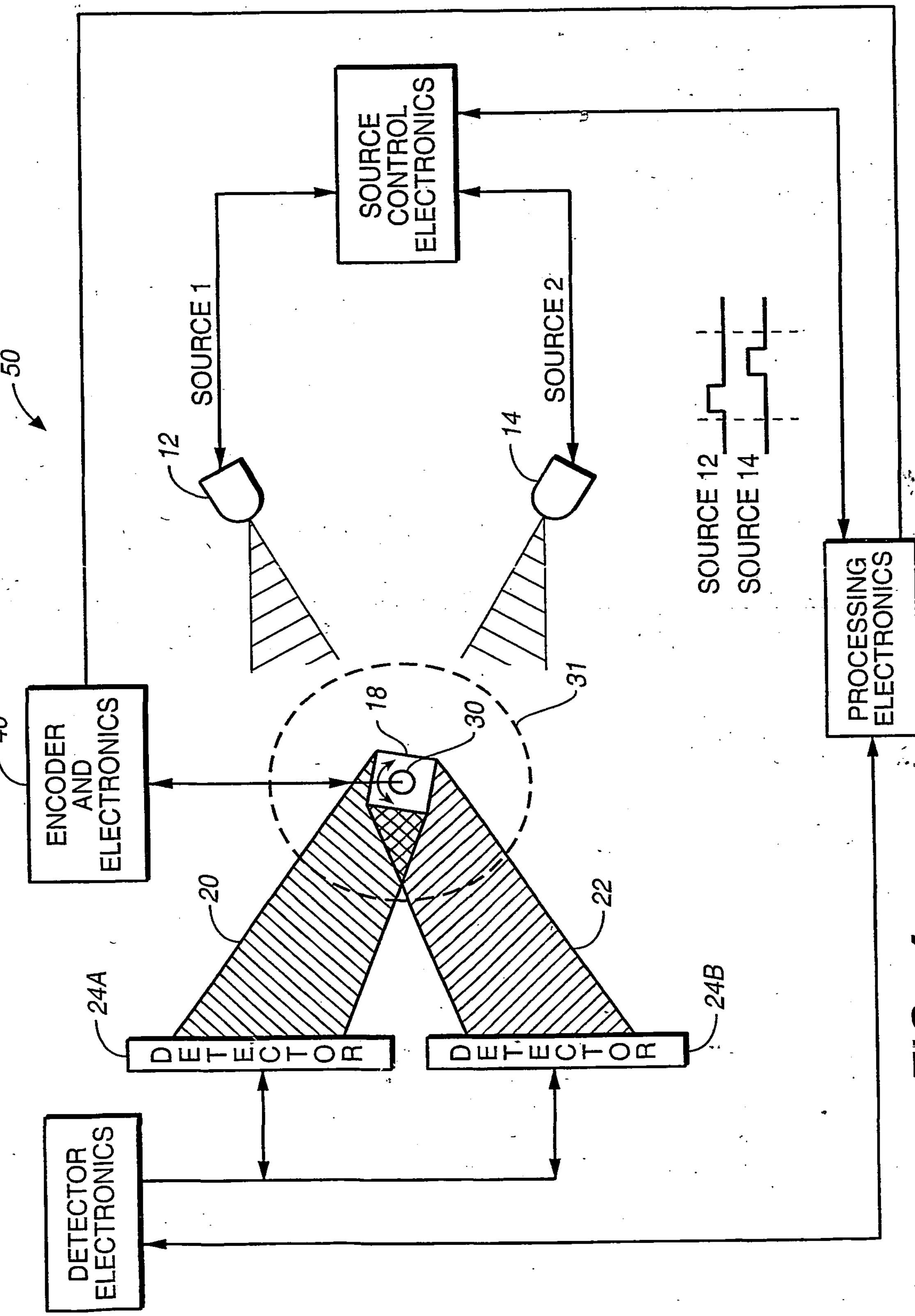
DETECTOR ELECTRONICS
36

FIG._3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SOURCE 14
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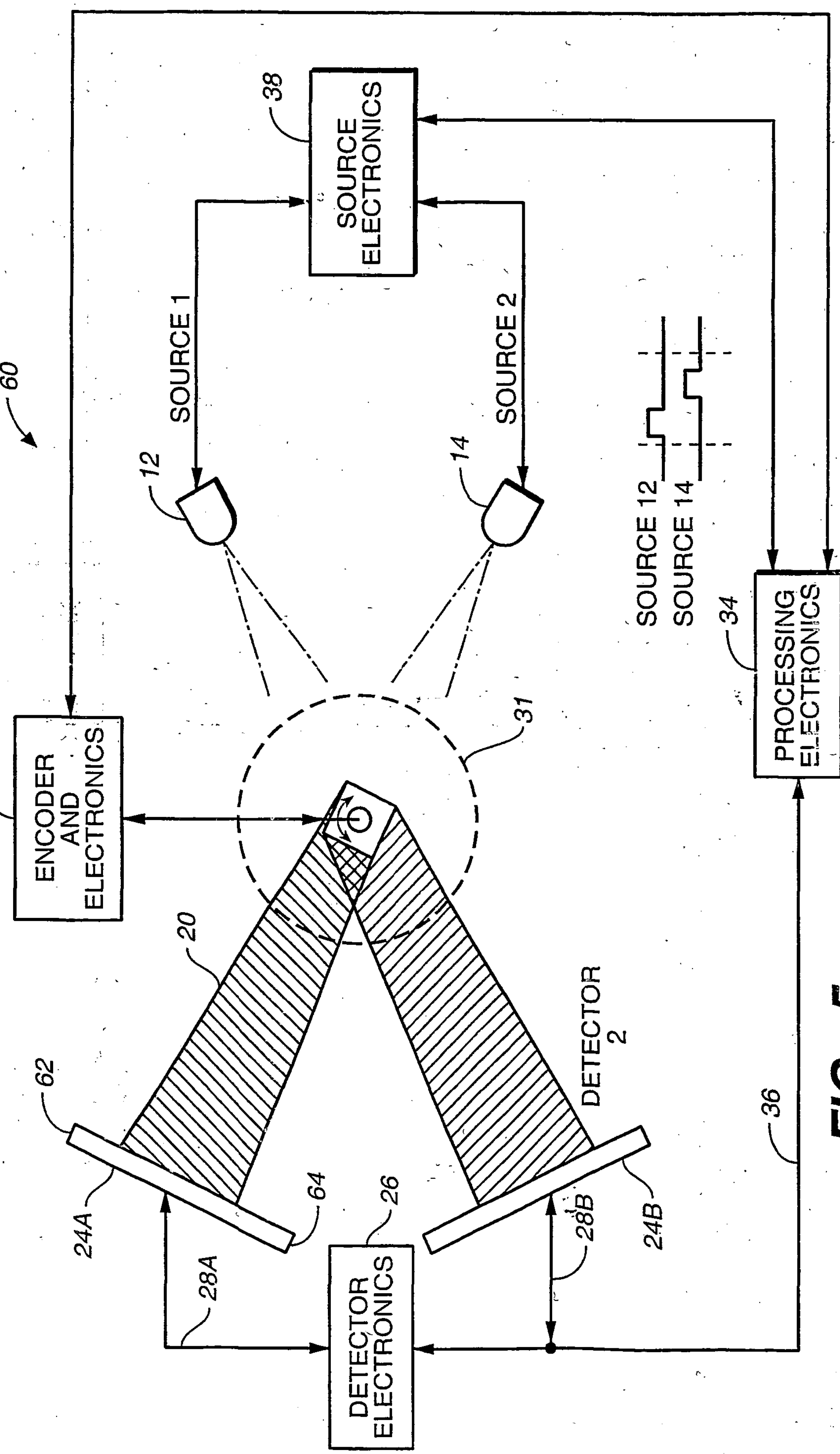
DETECTOR
DETECTOR
DETECTOR ELECTRONICS

FIG._4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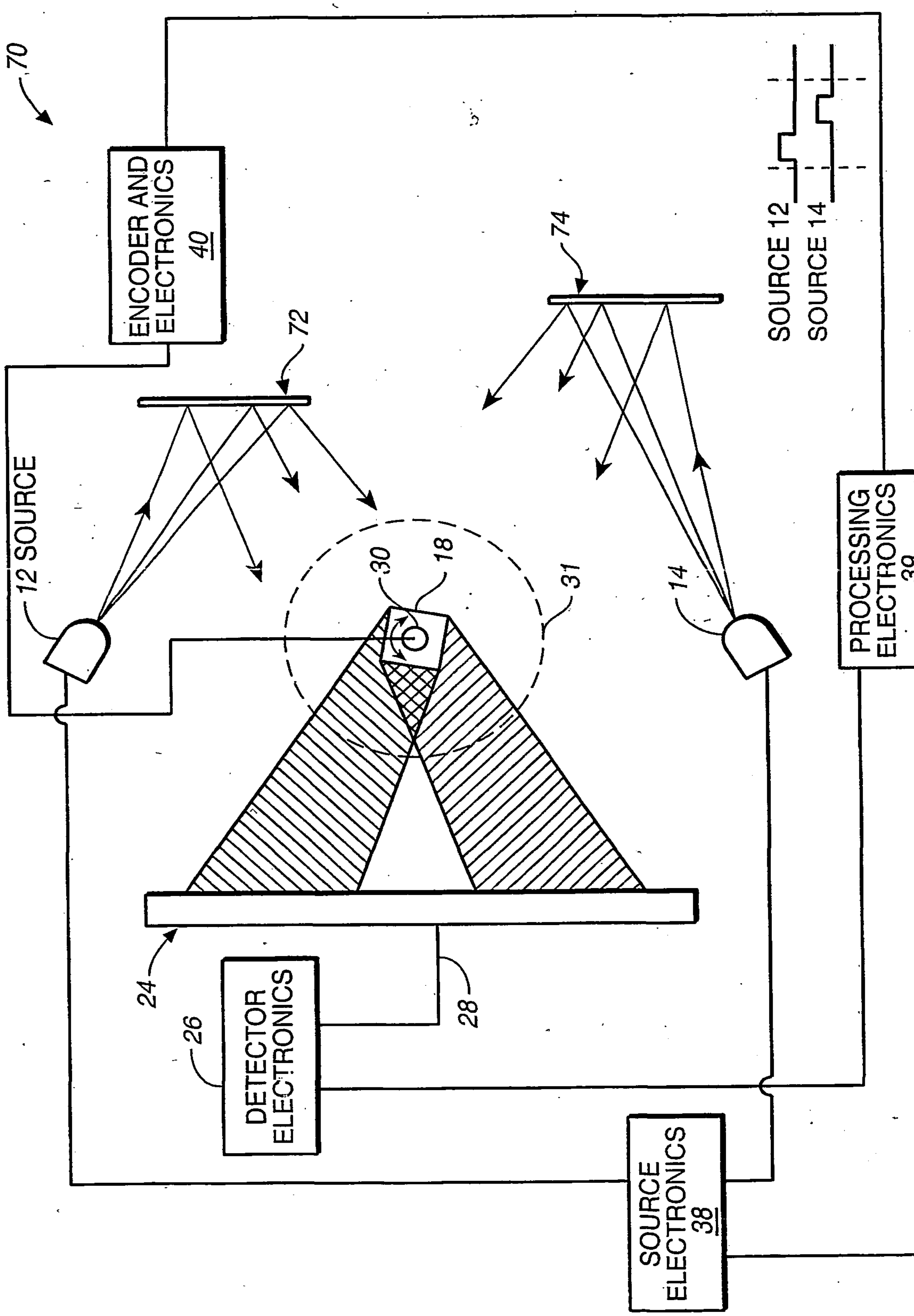
DETECTOR ELECTRONICS

FIG._5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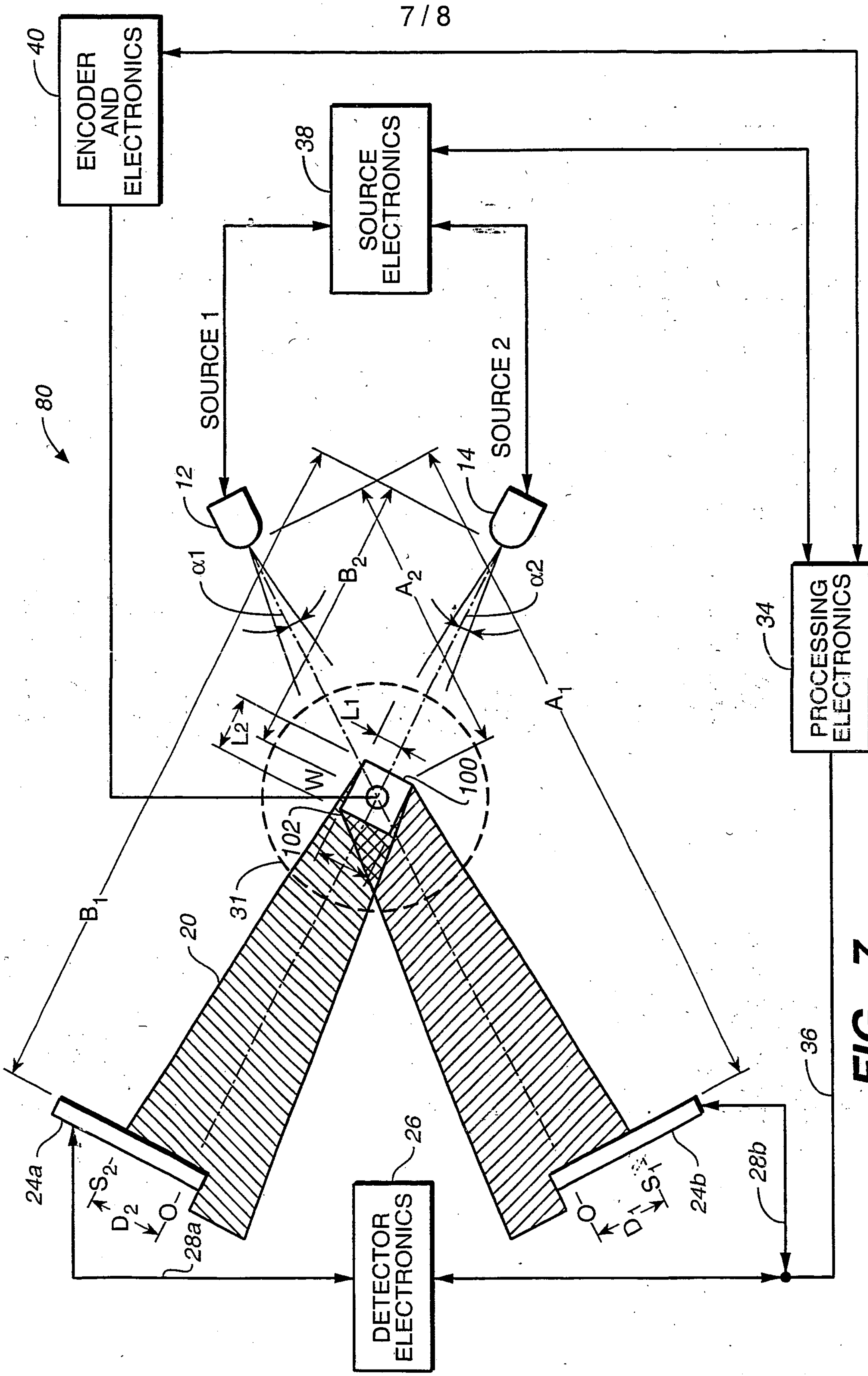
SOURCE ELECTRONICS 38

FIG._6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PROCESSING ELECTRONICS
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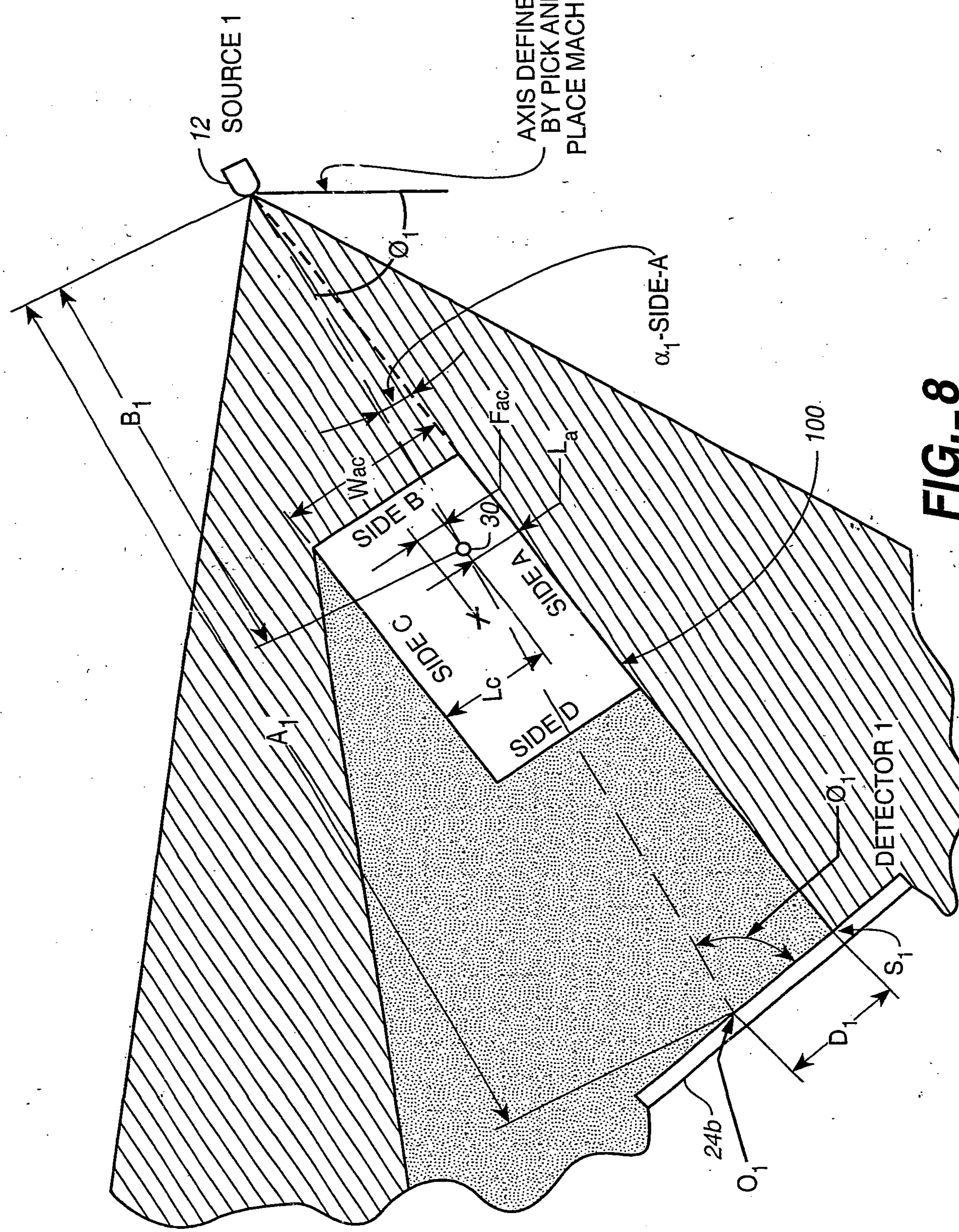
D2
S1
D1
O

FIG._7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$F_{ac}$
$W_{ac}$
$L_a$
100
SIDE B
30
SIDE A
SIDE C
$L_c$
SIDE D
$A_1$
DETECTOR 1
$Ø_1$
$S_1$
$D_1$
24b
$O_1$

FIG._8

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/00302

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 H05K13/04

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H05K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 5 687 475 A (DOEMENS GUENTER) 18 November 1997 (1997-11-18) the whole document | 1-7,9, 12,15-17 |
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☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,<br>Fax: (+31–70) 340–3016 | Rieutort, A |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter nal Application No
PCT/US 02/00302

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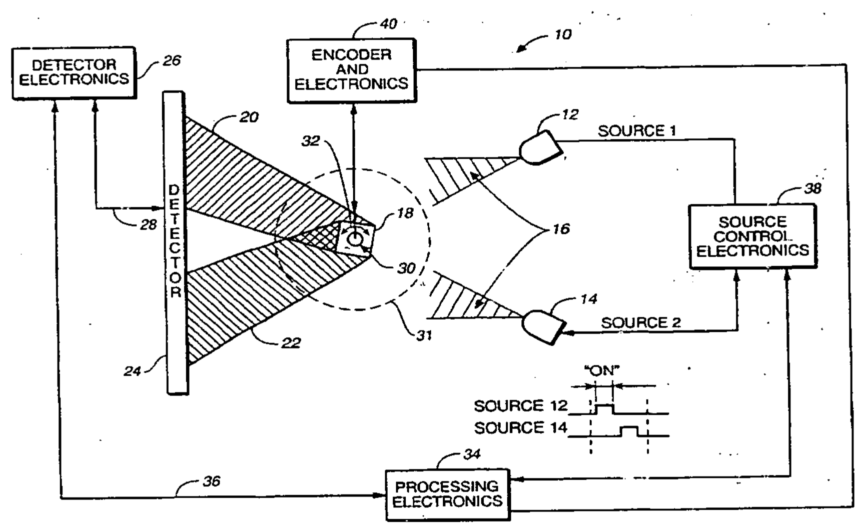
*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: IMPROVED LASER ALIGN SENSOR FOR POSITIONING COMPONENTS




(57) Abstract: A sensor (184) for sensing placement information of a component (18) to be placed by a pick and place machine (150) is disclosed. The sensor (184) includes a plurality of light sources (12, 14) each of which is disposed to direct illumination at different angles of incidence upon the component (18). Each source (12, 14) is further adapted to generate light based upon an energization signal. Source control electronics (38) are provided and coupled to the plurality of light sources (12, 14) to successively provide energization signals to each source (12, 14). A detector (24) is disposed within the sensor (184) relative to the plurality of sources (12, 14) to receive at least one shadow (20, 22) of the component (18), and provide data at a detector output indicative of the shadow (20, 22) imaged while the component (18) is rotated.

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**AMENDED CLAIMS**

[received by the International Bureau on 20 August 2002 (20.08.02); original claims 1 and 16 amended; claim 17 cancelled; remaining claims unchanged (5 pages)]

1. A sensor for sensing placement information of a component to be placed by a pick and place machine having a nozzle, the sensor comprising:

a plurality of light sources disposed to direct light at different angles of incidence upon the component, along a plane substantially perpendicular to the nozzle, wherein each source being adapted to generate light based upon an energization signal;

source control electronics coupled to the plurality of light sources to selectively provide the energization signal to each source; and

a detector disposed relative to the plurality of sources to receive at least one shadow portion of the component, the detector having a detector output providing data indicative of the at least one shadow portion imaged while the component rotates.

2. The sensor of claim 1, wherein all of the light sources are disposed to provide illumination in substantially the same plane.

3. The sensor of claim 2, wherein the detector is disposed in the same plane at the light sources.

4. The sensor of claim 1, and further comprising an encoder operably coupled to the nozzle to provide an encoder signal indicative of angular orientation of the nozzle.

5. The sensor of claim 1, wherein the detector comprises a plurality of detector portions.

6. The sensor of claim 5, wherein the plurality of detector portions are disposed contiguous to one another.

7. The sensor of claim 5, wherein the detector portions are coplanar with one another.

8. The sensor of claim 5, wherein the detector portions are not coplanar with one another.

9. The sensor of claim 5, wherein each detector portion is disposed to image a different part of the component, and each detector portion provides a group of data based upon an image of the at least one shadow portion, and wherein the groups of data include a characteristic cusp, wherein the characteristic cusp from a first group of data occurs at a different component orientation than a characteristic cusp from a second set of data.

10. The sensor of claim 5, wherein each of the detector portions is disposed to have a principal

axis oriented at an angle relative to another detector portion.

11. The sensor of claim 10, wherein the angle is about 90°.

12. The sensor of claim 1, wherein the plurality of light sources comprises at least three light sources.

13. The sensor of claim 1, and further comprising a specular reflector disposed between at least one source and the detector.

14. The sensor of claim 1, and further comprising a specular reflector disposed between the component and the detector.

15. The sensor of claim 1, wherein the source control electronics is further adapted to provide the energization signal to successive sources.

16. A pick and place machine, comprising:

a transport mechanism adapted to receive and move a workpiece relative to the pick and place machine;

a feeder mechanism including at least one feeder adapted to provide a plurality of components;

a placement head adapted to releasably convey components from the feeder mechanism to the workpiece;

a sensor for sensing placement information of a component to be placed by the pick and place machine, the sensor including:

a plurality of light sources disposed to direct light at different angles of incidence upon the component, along a plane substantially perpendicular to the nozzle, wherein each source is adapted to generate light based upon an energization signal;

source control electronics coupled to the plurality of light sources to successively provide the energization signal to each source; and

a detector disposed relative to the plurality of sources to receive at least one shadow portion of the component, the detector having a detector output providing data indicative of the at least one shadow portion imaged while the component rotates; and

an encoder coupled to the placement head to provide data indicative of component orientation; and

processing electronics coupled to the encoder, and the sensor, the processing electronics adapted to receive data from the detector output and the encoder, and provide command signals to the source control electronics, the processing electronics computing component placement information based upon data provided during rotation of the component.